Evaluating the Effects of In-Stream Disposal on Flood Levels

David A. Margo, P.E.[1]
Raymond A. Povirk, P.E.[2]

Abstract

The Lower Monongahela River Project consists of a two for three replacement of Locks and Dams 2, 3, and 4. The project is expected to produce more than 2 million cubic yards of excavation, concrete rubble, and dredged material that must be disposed. Consideration is being given to in-stream disposal of a portion of the excavated material. The proposal would reduce the cost of upland disposal and has the potential to improve river habitat.

Federal flood plain management requirements generally prohibit the placement of material in the river if flood levels would be increased. The impacts of in-stream disposal were initially modeled numerically using standard backwater computation software. As part of a value engineering proposal, a physical hydraulic model was constructed in an effort to improve the estimate of available disposal capacity.

A 1:100 scale physical hydraulic model was constructed to represent pools 4 and 5 of the Allegheny River. Baseline conditions were established for the 1% chance exceedence flood. Material was then placed in existing deep areas in various configurations to determine the maximum available disposal volume. The results showed a significant increase in disposal capacity compared to previous numerical modeling estimates.

Lower Mon Project. Locks and Dams 2, 3 and 4 on the Monongahela River in southwestern Pennsylvania are the three oldest currently operating navigation facilities on the Monongahela River. A vicinity map showing the project location is presented in Figure 1. The Lower Mon Project consists of a two for three replacement of Locks and Dams 2, 3, and 4. The 100-year old fixed crest dam at Locks and Dam 2 near Braddock is being replaced with a float-in gated dam. Two new lock chambers will be constructed at Locks and Dam 4 near Charleroi. Upon completion of the new Charleroi Locks, the facilities at Locks and Dam 3 near Elizabeth will be removed. Other items of work include navigation dredging within Pool 3, relocation of public facilities, and the future rehabilitation of Locks 2.

The removal of Locks and Dam 3 will lower the pool a nominal 3.2 feet upstream from Elizabeth to Locks and Dam 4 near Charleroi. Downstream from Elizabeth to Locks and Dam 2 at Braddock, the pool will raise a nominal 5.0 feet. A profile of the project is presented in Figure 2.

[1] Hydraulic Engineer, Pittsburgh District, 1000 Liberty Avenue, Pittsburgh, PA 15222
412.395.7353, David.A.Margo@usace.army.mil
[2] Hydraulic Engineer, Pittsburgh District, 1000 Liberty Avenue, Pittsburgh, PA 15222
412.395.7347, Raymond.A.Povirk@usace.army.mil

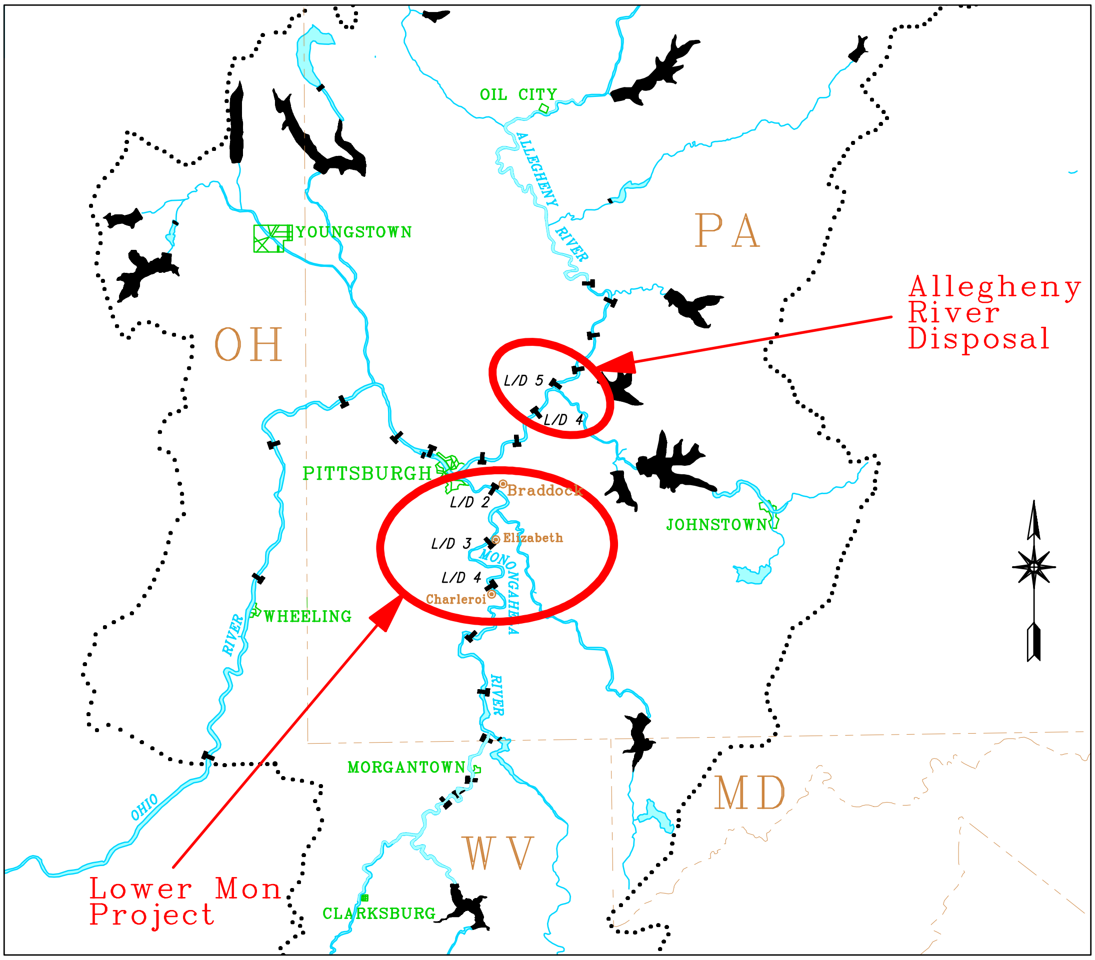

Figure 1. Lower Mon Project Vicinity Map

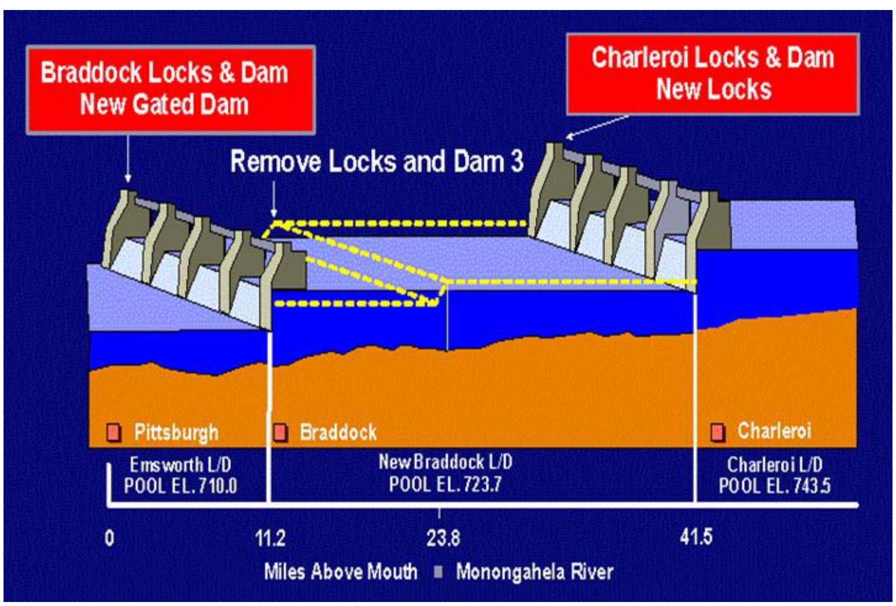

Figure 2. Lower Mon Project Profile

Disposal Alternatives. The project is expected to produce more than 2 million cubic yards of excavation, concrete rubble, and dredged material that must be disposed. A summary of disposal quantity estimates is presented in Table 1. Disposal options include the beneficial reuse of excavated and dredged material for brownfield remediation and underwater placement of rock and concrete rubble for aquatic reef habitat in the Monongahela River. Consideration is also being given to in-stream disposal of a portion of the excavated and dredged material. Any remaining material would be placed in an upland disposal site. The following paragraphs discuss the hydraulic design aspects related to development of in-stream disposal alternatives.

Table 1. Disposal Quantity Estimates

Work Item	Concrete Rubble (cy)	Rock Excavation (cy)	Common Excavation (cy)
Braddock Dam (L/D 2)	38,180	-	388,300
Charleroi Locks (L/D 4)	97,150	16,700	495,000
L/D 3 Demolition	56,200	-	12,000
Pool 3 Dredging	-	-	1,057,000
Totals	191,530	16,700	1,952,300

In Stream Disposal. To be suitable for in-stream disposal, material must meet the Pennsylvania Department of Environmental Protection (PADEP) guidelines for residential fill with respect to pollutants. An extensive sampling and testing program within Mon Pool 3 indicates that the dredged material would be of acceptable quality. In addition, induced water surface surcharges cannot exceed 0.1 feet for the 1% chance exceedence flood. This is the limit usually applied by PADEP for the effect of single encroachments. It also generally complies with federal flood plain management guidelines, which prohibit surcharges due to the placement of material within the floodway.

Monongahela River. Replacement of the fixed crest at Locks and Dam 2 with a gated structure caused a slight reduction in computed flood levels. Therefore, existing deep areas within the upper reaches of Pool 2 could be utilized for material disposal. The allowable disposal volume would be that which compensates for the reduced flood levels. Within Pool 3, the net effect of replacing Locks and Dam 2, removing Locks and Dam 3, and dredging is an even greater reduction in flood levels. This reduction provides the opportunity for additional in-stream disposal. To avoid impacts to navigation, disposal in pool 3 would be limited to maintain a channel depth of 13 feet. Because of this restriction, the allowable disposal volume would be considerably less than that which compensates for the reduced flood levels.

Allegheny River. Pools 4 and 5 of the Allegheny River have been extensively dredged for sand and gravel over the years. As a result, existing deep holes within these pools could be utilized for material disposal. Barges would be used to transport material from the Lower Mon Project site to the Allegheny River. By filling in these anoxic holes, PADEP anticipates an improvement in river habitat within these reaches.

Numerical Model. Initial estimates of disposal capacity within the Monongahela and Allegheny Rivers were developed using standard step backwater computation software (HEC-2, HEC-RAS). Numerical models were developed using existing sounding data. Baseline conditions were established for the 1% chance exceedence flood event. The cross sections were then modified to represent various configurations of disposal placed uniformly across the channel bottom. The 1% chance exceedence flood was computed for each configuration and compared with the baseline. Alternatives that increased the computed flood levels more than 0.1 feet were rejected.

Monongahela River. Relatively deep reaches of Pools 2 and 3 capable of accepting dredged material were identified and modeled from soundings taken in 1990 and 1991. Cross sections were spaced at approximately 1/4 mile intervals. Within Pool 2, an estimated 400,000 cy of material could be placed between river mile 19.5 and 23.5. A profile of this reach is presented in Figure 3. Within Pool 3, approximately 370,000 cy of disposal capacity is available mostly between river mile 23.9 and 29.0. A profile of this reach is presented in Figure 4.

Allegheny River. Reaches of Pools 4 and 5 with capacity for disposal were identified and modeled from soundings taken in 1992 (Pool 5) and 1996 (Pool 4). Cross section spacing varied, but was generally 1/4 mile or less. Within Pool 4, an estimated 118,000 cy of material could be placed throughout the reach. A profile of this reach is presented in Figure 5. Within Pool 5, an estimated 248,600 cy of material could be placed throughout the reach. A profile of this reach is presented in Figure 6.

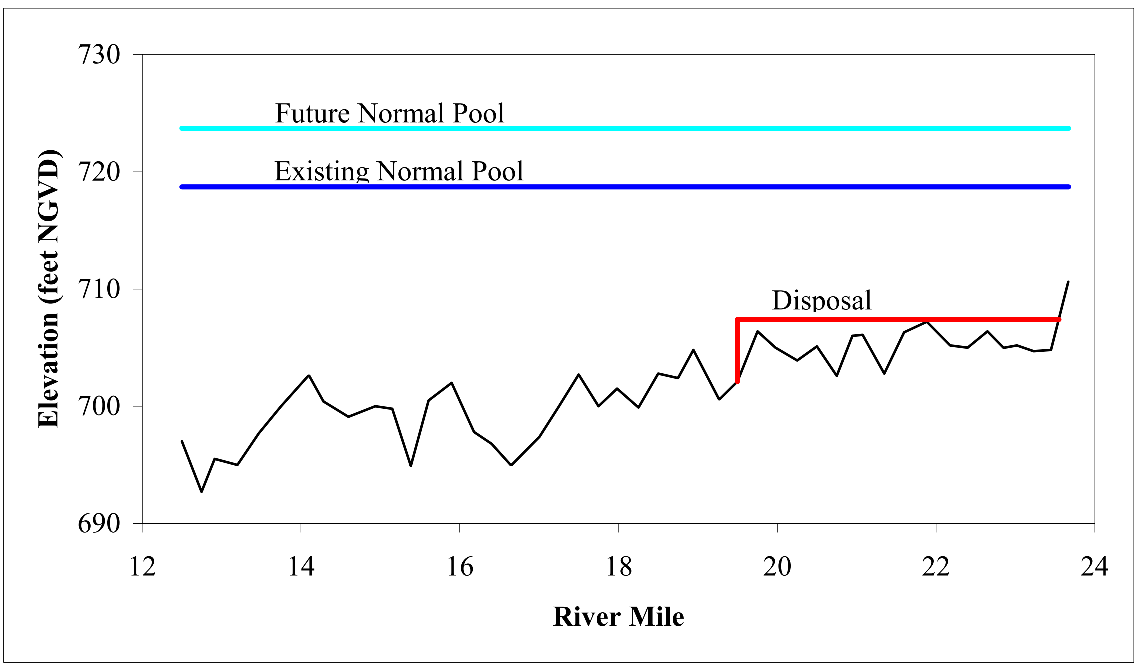

Figure 3. Profile of Monongahela River Pool 2

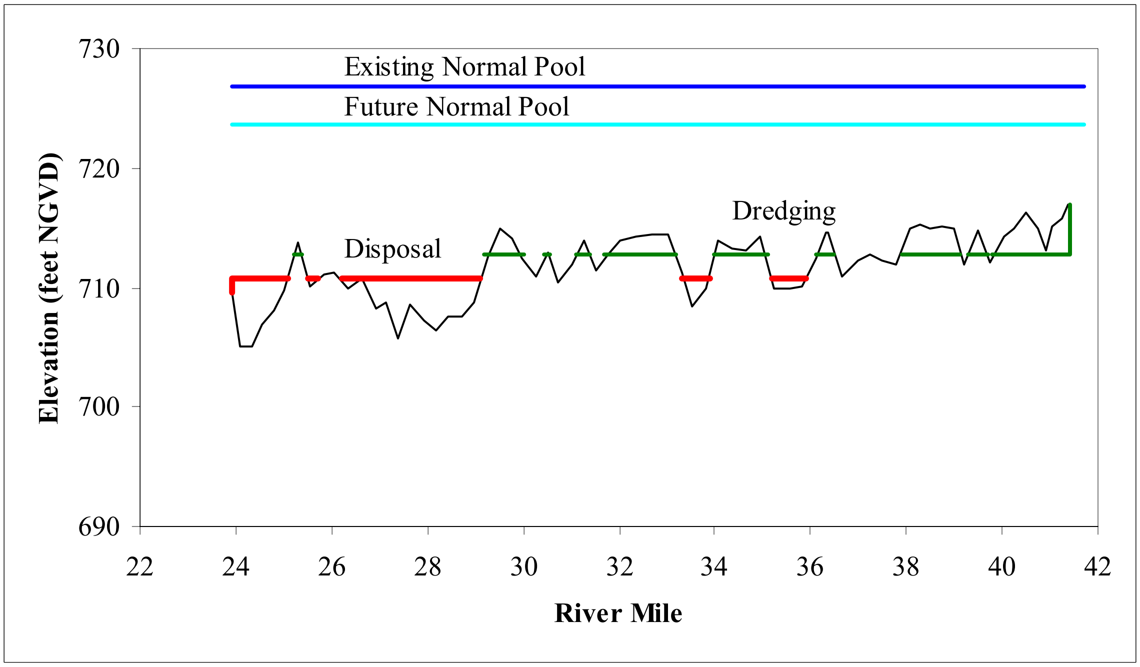

Figure 4. Profile of Monongahela River Pool 3

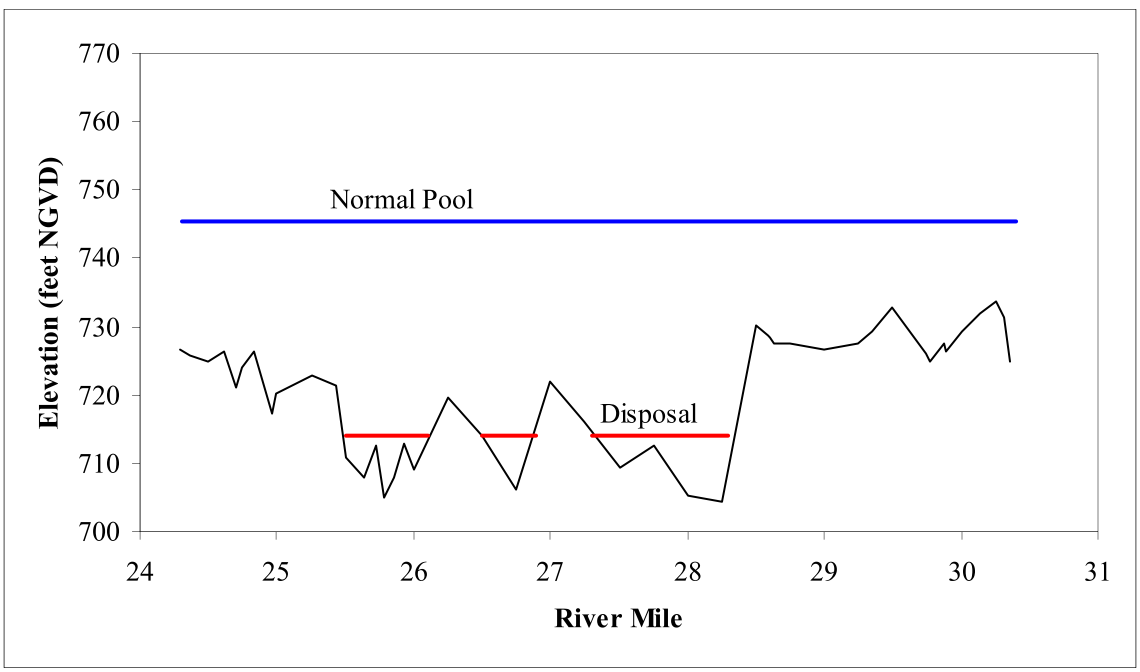

Figure 5. Profile of Allegheny River Pool 4

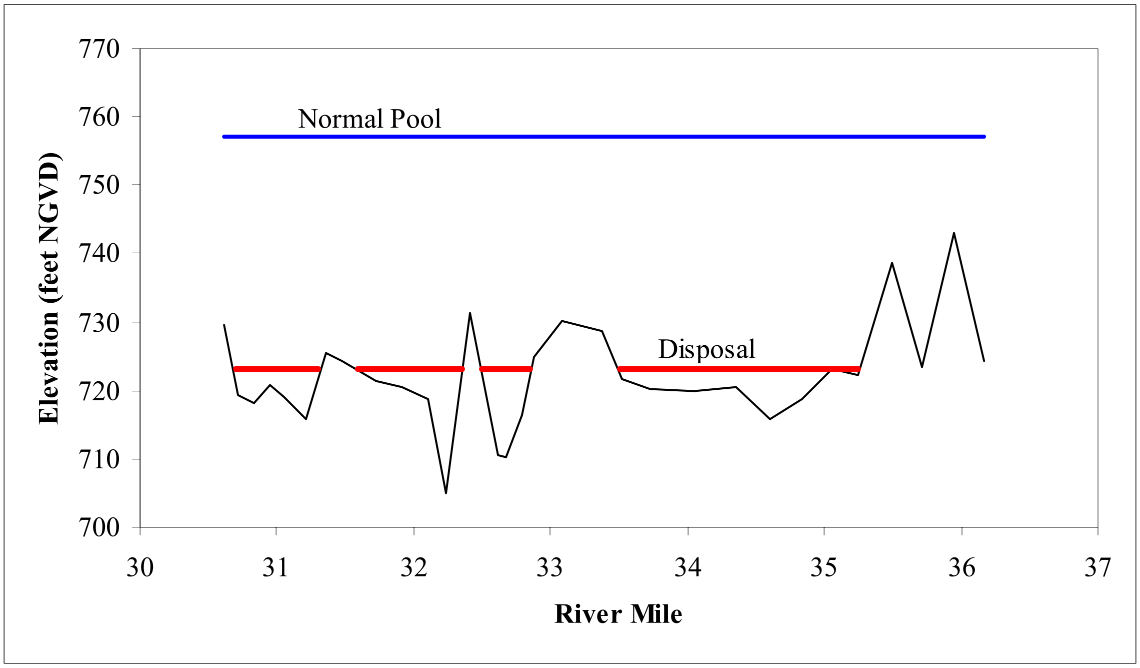

Figure 6. Profile of Allegheny River Pool 5

Value Engineering Proposal. In 1998, a value engineering proposal suggested a physical hydraulic model to refine disposal quantity estimates for Allegheny River Pools 4 and 5. The purpose was to more accurately represent flow conditions in and around the deeper holes so that disposal capacity could be maximized. Model testing for the Monongahela River reaches was not proposed because the holes were not very deep and the potential benefit of model testing was deemed negligible. The value engineering proposal was adopted and the model testing program began in 1999.

Physical Hydraulic Models. The physical models were constructed at the Coastal and Hydraulics Laboratory (CHL) of the Corps Engineer Research Development Center (ERDC). An undistorted scale of 1:100 was used to represent the major portions of Pools 4 and 5 within the Allegheny River. The fixed-bed type models were based on contour drawings derived from soundings taken in 1992 and 1996. Cross section templates made of sheet metal were installed with contours sketched and molded by hand between the templates using mortar. A photograph of the model for Pool 4 is presented in Figure 7.

A series of piezometers were installed along the model reaches to record water surface elevations. Discharge was controlled by a venturi flow meter connected to a manometer and the downstream elevation boundary condition was controlled by an adjustable tailgate.

Baseline conditions for the model were established from published discharges for the 10% and 1% chance exceedence events, which varied somewhat from the water surface elevations computed using one-dimensional backwater models (HEC-2, HEC-RAS).

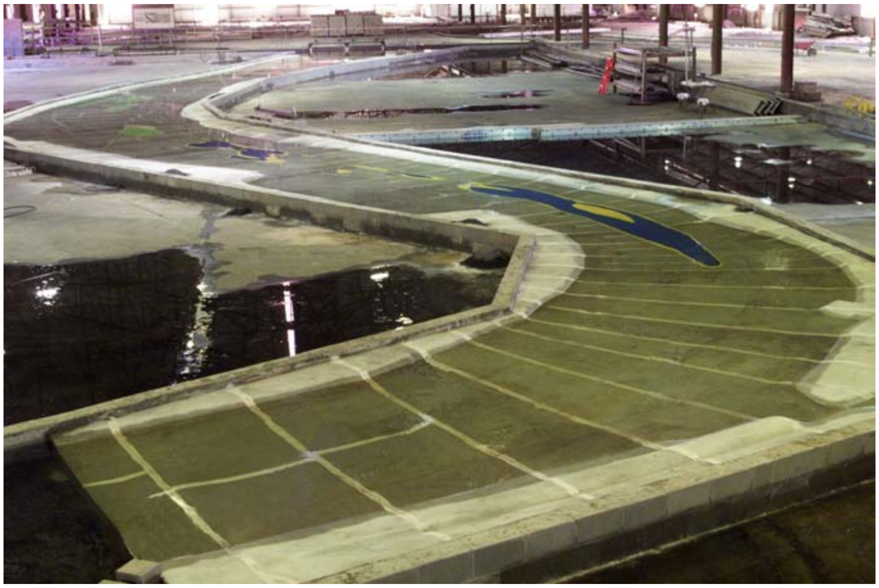

Figure 7. Physical Model of Allegheny River Pool 4

Temperature Effects. During testing, an apparent increase in the observed water surface occurred each afternoon. Because temperatures in the test hanger frequently exceeded 100° F, it was assumed that the heat was affecting either the actual water surface or the gage readings. The typical increase was only 0.001 feet in the model (0.1 feet prototype) with a maximum of 0.003 feet (0.3 prototype) at one of the gages. This effect would normally not be a concern for a navigation type model; however, it was considered significant in this case considering the 0.001 feet (0.1 feet prototype) criteria being used for allowable surcharge.

To minimize heat induced errors, a method was developed to evaluate cumulative heat in the model. Hourly temperature readings were multiplied by the time duration between readings. The resulting degree-hours were then accumulated throughout the day and reset to zero at midnight. Tests indicated that for accumulated heat below 1350 degree-hours, the results were reasonably consistent and repeatable. A maximum acceptable cumulative heat level of 1350 degree-hours was adopted and testing was discontinued for the day when this level was exceeded.

Initial Model Results. Material was placed in designated holes in varying configurations to maximize disposal without increasing the observed water surface more than 0.001 feet (0.1 feet prototype) at any location. The adopted configuration showed a capacity of 127,200 cy in Pool 4 and 298,000 cy for Pool 5. This represents an increase in total disposal capacity of approximately 16% over the numerical model estimates.

Updated Bathymetry. Detailed soundings were obtained on a 30-foot grid pattern in 2000 and 2001 to better define and monitor material placement.

Within Pool 4, the area designated as Hole 1 showed potential for a significant increase in disposal capacity due to the irregular scalloped pattern left in the riverbed by dredging operations. A decision was made to rebuild and retest this portion of the reach. Traditional model construction techniques were not suitable for this effort due to the level of detail provided by the newer survey. Instead, the updated bathymetry was cut into a foam bed using a computer controlled three-axis router. The foam was mounted on sheets of marine grade plywood and cut by the router to a depth of 1/8 inch, normal to the surface, lower than the measured bathymetry. The foam was then coated with two layers of fiberglass at 1/16-inch thickness each. The finished sections were then placed back on the router to delineate one-foot contour intervals. By hand painting the area between contours, material placement could be accurately monitored. A photograph showing a the reformed Hole 1 is presented in Figure 8. Comparison with Figure 7 demonstrates the dramatic improvement in the level of detail that can be modeled using the fiberglass coated foam sections. After installing the new sections, baseline conditions were reestablished. A self-leveling fiberglass resin was then placed in Hole 1 to the previously estimated elevations. A picture showing a partially filled hole is presented in Figure 9. Observed water surface surcharges were less than 0.001 feet (0.1 feet prototype) at all gages. The revised disposal plan showed an increase in capacity to 432,600 cy within Pool 4.

Within Pool 5, significant additional capacity was identified in several areas due to recent commercial dredging. Modifications were not made to the physical model due to funding constraints. As a result, the 1992 survey previously modeled was assumed to adequately represent baseline conditions. The disposal quantity could then be estimated as the sum of the initial model quantity estimate and the estimated quantity of dredging that had occurred between 1992 and 2001. The updated disposal quantity estimate for Pool 5 is 1,200,000 cy.

Figure 8. Reformed Section of Hole 1 in Allegheny River Pool 4

Figure 9. Hole Partially Filled with Fiberglass Resin in Allegheny River Pool 4

Summary. A summary of disposal quantity estimates for the numerical and physical modeling is presented in Table 2. Using existing cross section sounding data and traditional construction methods, the physical hydraulic model showed a 16% increase in the total available disposal capacity over the numerical model estimates. Capacity estimates were further refined through acquisition and testing of updated and more detailed bathymetry. Model tests for Pool 4 confirmed that disposal quantity estimates could be increased significantly without increasing the water surface more than 0.001 feet (0.1 feet prototype).

Results of the study suggest that physical hydraulic models can be effectively used to evaluate the impact of in-stream disposal on flood levels. In addition, the need for bathymetry that is current and detailed proved to be a key factor in the evaluation.

Table 2. Disposal Capacity Estimates for Allegheny River

Location	Numerical Model (cy)	Physical Model (cy)	Updated Bathymetry (cy)
Pool 4	118,000	127,200	432,600
Pool 5	248,600	298,000	1,200,000